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Japan: A Different Model of Mathematics Education

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Undergraduate and K–12 mathematics education in the United States have seen many reforms during the past decade. With the initial results of the Third International Mathematics and Science Study (TIMSS) appearing in October, 1996, there is also considerable interest in mathematics education elsewhere, especially Japan. A major revision in the K–12 curriculum in Japan has recently occurred, and the Mathematical Society of Japan has formed the Working Group for Undergraduate Mathematics, a committee of educators and mathematicians, to examine undergraduate mathematics education in Japan.

The success of the Japanese educational system in producing students who excel in mathematics is well-known and is pointed out in the results of TIMSS. This study was sponsored by the International Association for the Evaluation of Educational Achievement and involved approximately fifty nations world-wide. TIMSS focused on grades four, eight, and twelve, with Germany, Japan, and the United States receiving special attention [16; 17]. Unlike the National Council of Teachers of Mathematics *Standards*, which merely makes recommendations for K–12, Japan has a nationally set curriculum [5; 6; 12]. Since a fifth grade mathematics class in Tokyo will be covering roughly the same material as a class in Nagasaki or Sapporo during any given time of the academic year, Japanese educators have an opportunity to collaborate and polish lessons on a nationwide scale. This is not the case in U.S. schools, where the curriculum is locally controlled. In fact, the "TIMSS study of curricula found that current U.S. standards are unfocused and aimed at the lowest common denominator. In other words, they are a mile wide and an inch deep" [17]. In Japan, on the other hand, the achievements of students reflect the benefits of coherent goals and focused teaching practices. However, there is some question on how well the *Standards* have been implemented on a wide scale in the United States [17].

The purpose of this essay is to describe the Japanese educational system (with special emphasis on the mathematics component), and to compare and contrast it with that in the U.S.

K–12 Mathematics Education

In Japan, Munbusho, the Japanese Ministry of Education, sets the number of class periods for the year, the length of the class periods, the subjects that must be taught, and the content of each subject for every grade in K–12. For this reason, changes in the Japanese educational system are usually introduced more cautiously than in the United States, and possible curriculum revisions are evaluated more carefully before being put into effect. Technology-based courses of the type that one often sees in U.S. classrooms are not as popular in Japan, and Japanese educators generally seem to prefer a more traditional, theoretical, and problem-solving based course. Even though the current curriculum standards encourage the use of calculators beyond the fifth grade, calculators are still not allowed in many Japanese classrooms, since university entrance exams do not permit their use. Computers seem to be more prevalent in the Japanese classroom than hand-held technology [5; 6; 12; 13].

The elementary school curriculum is specified in Japan for grades 1–6. The goals and objectives of mathematics education at the elementary school level are to develop in children fundamental knowledge and skills with numbers and calculations, quantities and measurements, and basic geometric figures. In grades 1–3, children learn about the concept of numbers and how to represent them, the basic concepts of measurement, how to observe shapes of concrete objects and how to construct them, and how to arrange data and use mathematical expressions and graphs to express the sizes of quantities and investigate their mathematical relationships. They acquire an understanding of addition, subtraction, and multiplication, learn how to do basic calculations up to the multiplication and division of whole numbers, and learn how to apply these calculations. Children also become acquainted with decimal and common fractions during this time. The *soroban* or abacus is introduced in grade 3. Children learn basic concepts of measurement such as reading a clock, comparing quantities of length, area, and volume, and comparing sizes in terms of numbers. They are also taught the concepts of weight and time and shown how to measure fundamental quantities such as length [6].

By the end of grade 4, children are expected to have mastered the four basic operations with whole numbers and how to effectively apply them. They also should be able to do addition and subtraction of decimals and common fractions. In grades 5 and 6, children learn how to multiply and divide decimals and fractions. They are taught to understand the concept of area and how to measure the area of simple geometric figures and the size of an angle, as well as to understand plane and solid geometric figures, symmetry, congruence, and how to measure volumes. Children learn about the metric system during this time. Teachers show how to arrange data and use mathematical expressions and graphs to help children to become able to express the sizes of quantities. Letters such as x and a are introduced. Children also begin to learn about statistical data by using percentages and circle graphs (pie charts). It is recommended that calculators be introduced into the classroom in grade 5 to ease the computational burden [6].

Lower secondary school in Japan consists of grades 7–9. Preparation to get into the best high schools and universities begins at this time. There is tremendous pressure on students to perform well. Students are asked to learn a tremendous amount of material in grades 7–12, which is perhaps one of the major reasons why university and secondary school classrooms are often subdued. In contrast, elementary classrooms tend to be lively, with a great deal of interaction between students and teachers. In either case, classrooms are teacher-directed. The student-directed group learning that is found in some U.S. classrooms is virtually nonexistent in Japan.

In grade 7, students learn about positive and negative numbers, the meaning of equations, letters as symbols, and algebraic expressions. By the end of grade 8, they are able to compute and transform algebraic expressions using letter symbols and to solve linear equalities and simultaneous equations; they have also been introduced to linear functions, simple polynomials, linear inequalities, plane geometry, and scientific notation. In grade 9, students learn how to solve quadratic equations (those with real solutions) and are taught the properties of right triangles and circles, functions, and probability. In grade 7 and beyond it is recommended that calculators and computers should be efficiently used as the occasion demands [6].

In high school (grades 10–12), six mathematics courses are offered: Mathematics I, II, III and Mathematics A, B, and C. Although only Mathematics I is required of all students, those students intending to enter a university will usually take all six courses. In fact, Japanese high school students who take all of the courses offered will know more mathematics than many U.S. students do when they graduate from college. In Mathematics I, students are taught quadratic functions, trigonometric ratios, sequences, permutations and combinations, and probability. Mathematics II covers exponential functions, trigonometric functions, analytic geometry (equations of lines and circles), as well as the ideas of limits, derivatives, and the definite integral. Calculus is taught in Mathematics III, including functions and limits, sequences and geometric series, differential and integral calculus. More advanced topics such as Taylor series are usually not taught in Mathematics III. Mathematics A deals with numbers and algebraic expressions, equalities and inequalities, plane geometry, sequences, mathematical induction, and the binomial theorem. Computation and how to use the computer are also taught in this course. In Mathematics B, students learn about vectors in the plane and 3-space, complex numbers and the complex number plane, probability distributions, and algorithms. Mathematics C consists of a variety of topics, including matrix arithmetic (up to 3×3 matrices), systems of linear equations and their representation and solution using matrices, conic sections, parametric representation and polar coordinates, numerical computation including the approximate solution of equations and numerical integration, and some calculus-based statistics [6; 20].

The University Entrance Exams

The importance of university entrance exams in Japan cannot be overstated, since admission to the "right" university may dictate one's future career and social status. From the time that a student enters lower secondary school, much of the Japanese educational system is dedicated to preparing students to pass the university entrance exams. Throughout high school (and before) students often attend *juku* and *yobiko* after regular school hours or during holidays. These are special cram schools that prepare students for the university entrance exams.

The University Entrance Center Examination (UECE) is similar to the SAT exam given in the United States. The entrance exam to public universities consists of two parts. The standardized primary exam, the first part, is offered once per year in mid-January. This exam is administered by Munbusho. The secondary exam is offered by each university at a later date. Usually the exams are weighted about 50–50; however, at some prestigious universities the secondary exam is given more weight. The University of Tokyo counts the secondary exam as 80%. Private universities will either use the UECE or use their own exam. A small percentage of students, usually at private universities, do not have to take the examinations and are admitted by recommendation [19].

University Mathematics Education

In Japan, the school year begins in April and ends the following March. Most universities are on the semester system; however, a few institutions use the quarter system. The first semester runs from the beginning of April until mid or late July. The second semester begins in mid-September and ends in early February. Undergraduate classes in Japan tend to meet less often than those in the United States. While students in a freshman calculus class in the U.S. meet three to five times a week, it is not uncommon for the same class in Japan to meet only once a week for a 90 minute period and cover the same amount of material.

We often hear that students in Japan work very hard in high school and that their time at the university is a four-year vacation. This may be true at many universities and in certain disciplines; however, there are other universities that demand that their students work hard. Those who choose to major in disciplines such as engineering and medicine are very serious students.

Although the undergraduate mathematics major in Japan is perhaps more theoretically oriented, the course of study is similar to what we see in the United States. The actual curriculum varies with each university, but the first three semesters typically consist of a repeat of single variable calculus followed by multi-variable calculus. The undergraduate calculus course is much more rigorous than the high school course. At the upper level, students are expected (but not necessarily required) to take the usual courses in linear algebra, real and complex analysis, geometry and general topology, and algebra. Often a thesis or a senior seminar is required. Technology in the classroom seems to be more prevalent at the university undergraduate level than in K–12; however, graphing calculators and computer algebra systems are nowhere near as popular as they are in the United States [1; 3; 13; 20].

Like many U.S. professors, university professors in Japan are not satisfied with their incoming students. In a recent Mathematical Society of Japan survey, 80% of the university professors surveyed felt that the mathematical ability of incoming students has declined. Between November 1995 and January 1996, approximately 150 teachers were surveyed at public and private universities. Of the 84 responses received, 78% felt that the mathematical abilities of university students had declined, and no one indicated that the situation had improved. The majority of the respondents felt that abstract, logical, and mathematical thinking ability had declined. The responses also indicated that foundational skills, the ability to read and understand Japanese, and the ability to apply mathematics had deteriorated. Some respondents also felt that the ability to calculate had declined and that there was greater student apathy. Responses to the survey indicated that the problem was K–12 education and the university entrance exam system. They felt that there was a decrease in the amount of time spent in the classroom on mathematics and that the memorization model of study for the university entrance exams was a detriment to learning abstract thinking and problem-solving skills [18].

Considerable collaboration between Japan and the United States in K–12 mathematics education has occurred; but similar cooperation is only beginning to materialize at the calculus level and beyond [2; 3; 4; 13; 15; 20]. There is also a growing interest in using technology to teach mathematics in Japan and other Asian countries. The First Asian Technology Conference in Mathematics, held in Singapore in December, 1995, was well-attended by mathematicians and educators from Japan, other Asian-Pacific countries, Europe, and the United States [1]. The next two ATCM conferences are scheduled for June, 1997 in Penang, Malaysia and August, and 1998 in Tsukuba, Japan. In 2000, the Ninth International Congress of Mathematics Education will be held in Chiba, Japan.

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